Moscow Institute of Electronic Technology

Dialysis technologies

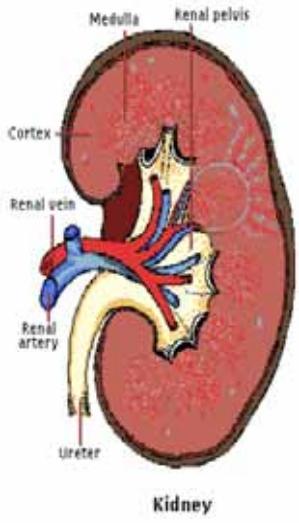
Kidneys

☺ Remove toxic by-products of the metabolism and molecules smaller than 69000Da

☺ Regulate body fluid composition and volume

☺ Provide resorption of salts (Na+, K+, Cl-), glucose, creatine, proteins, and water

☺ Contribute to the regulation of blood pressure, hemodynamic and acid base balance of body

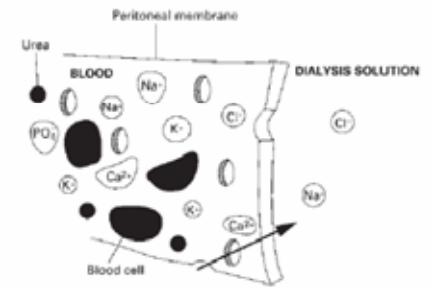


Kidney

Blood and dialysate composition

Blood: dark red, viscous slightly alkaline suspension (pH 7.4) of cells – erithrocytes, leukocytes, thrombocytes suspended in plasma.

Plasma: water (90%), proteins (9%) and inorganic salts, ions, nitrogens, nutrients and gases (1%)



Dialysate: reverse osmosis water, dextrose and different electrolytes like calcium-, potassium-, magnesium-, sodium chloride and sodium acetate or bicarbonate

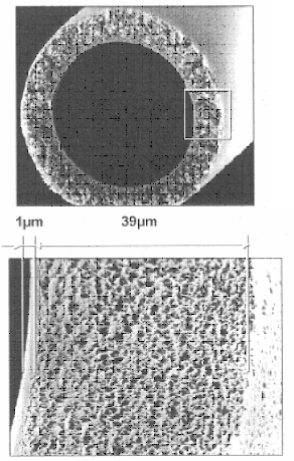
Physical and microbiological characteristics of dialysate are also importaint

Membranes for dialysis

☺ *Unmodified Cellulosic Membranes*
Cellobiose + high density of hydroxyl groups
Fibers can be manufactured to have low wall thickness and high porosity
Have low mean pore size
Hydrophilic.

☺*Modified Cellulosic Membranes*
Retain the desirable diffusive properties
Have larger mean pore size
Associated with less-pronounced complement activation (high percentage of hydroxyl groups are substituted with a relatively small chemical compound (e.g. cellulose diacetate, cellulose triacetate))

☺ *Synthetic Membranes*
synthetic membranes are thicker (>20μm)
May be either symmetric or asymmetric
Asymmetric structure implies a blood-contacting 'skin' layer (pores 30–50 Å) and support layer (pores 100 Å)



Synthetic polysulphone membrane

Driving forces of mass transfer

$$J = -D_S \cdot A \cdot \frac{\Delta C}{\Delta x}$$

J the net solute flux (mol/s), DS the solute diffusivity (m^2/s) being a unique property of the solute-solvent at a specific temperature, A the area of diffusion (m^2) and $\Delta C/\Delta x$ the concentration difference (mol/m^3) over the membrane thickness (m)

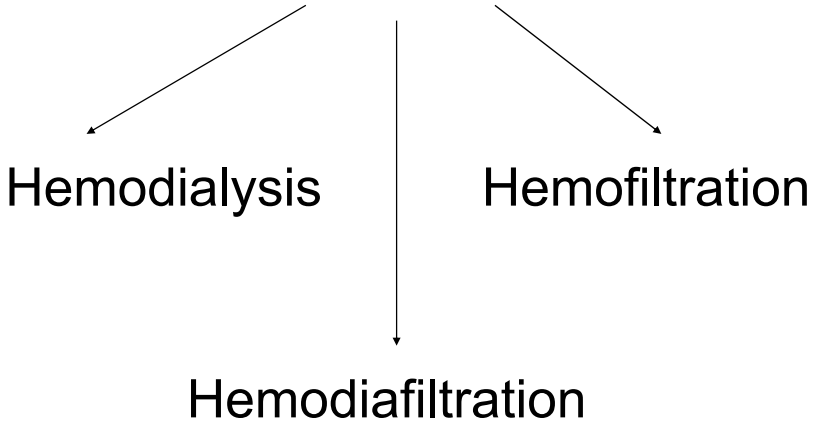
$$J_u = h_m \cdot A \cdot \Delta P$$

Ju the volumetric flux (m^3/s), hm the hydraulic permeability (m/s/Pa), A the area of ultrafiltration (m^2), and ΔP the pressure difference (Pa)

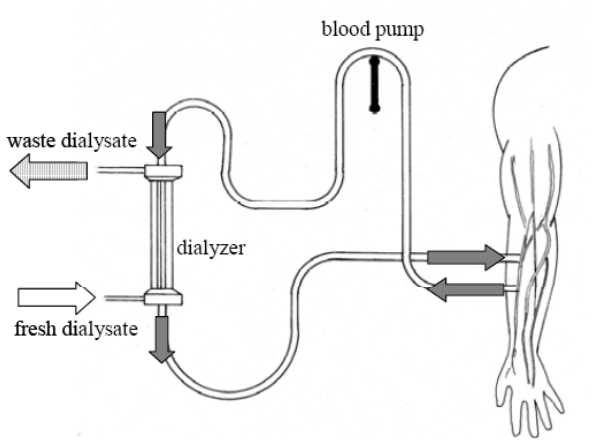
$$\Delta\pi = \sigma \cdot R \cdot T \cdot \Delta C$$

σ the reflection coefficient of the membrane (-), R the universal gas constant (8.314J/mol/K), T the absolute temperature (K) and ΔC the concentration difference (mol/L)

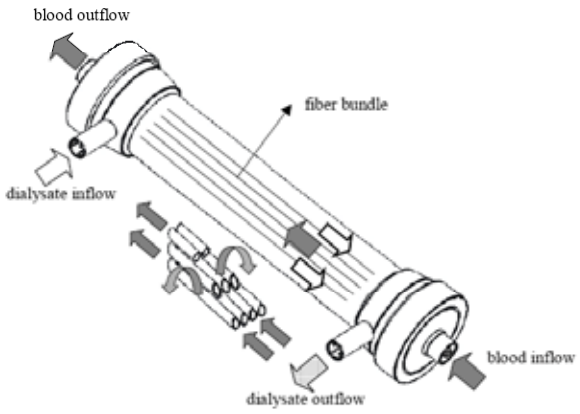
Dialysis technologies



Extracorporeal circuit in hemodialysis



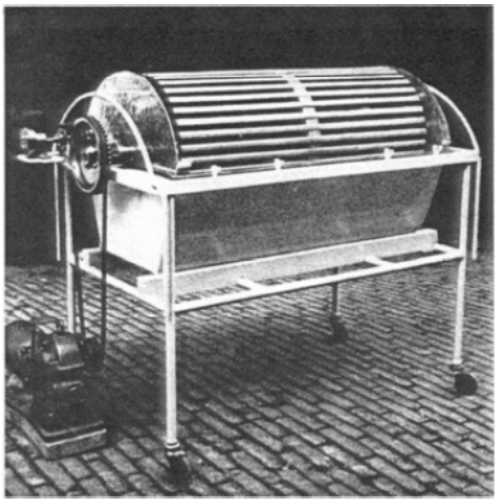
Hollow fiber dialyzer



History of hemodialysis

- 1861 Thomas Graham. Hoop dialyzer
- 1913 John Abel. Vividiffusion apparatus named “artifitial kidney”
- 1914 Von Hess and McGuigan. Pulsate blood flow and turbulent dialysate flow
- 1920 Love. Membranes from chicken intestines
- 1923 Heinrich Nechles. Goldbeater’s skin
- 1924 Heorg Haas. Performed first human dialysis
- 1928-1937. Heparin became available, cellophane became commercial

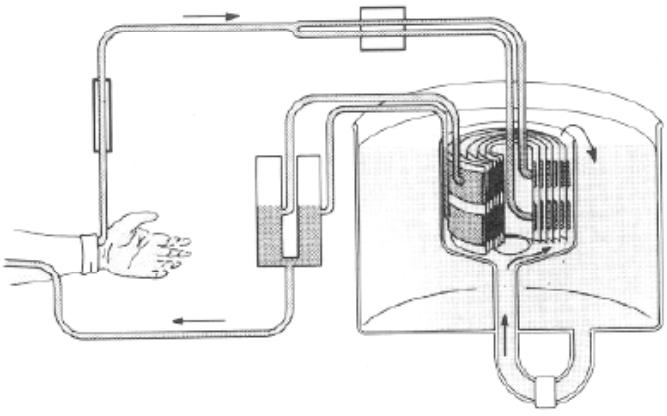
Kolff’s original rotating drum (1943)



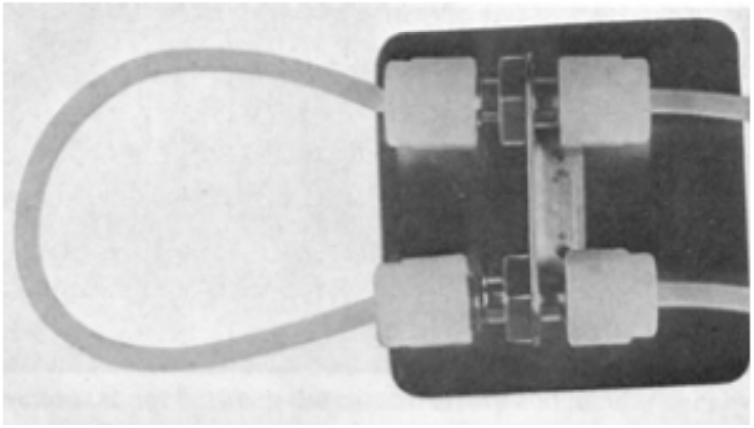
History of hemodialysis

- 1946 Nils Alwall. First dialyzer with controllable ultrafiltration
- 1946 Murray. Static coil
- 1947 Von Garrelts. Developed a precursor of the coil type cellophane tubing wrapped together with a spacer
- 1947 MacNeil. Parallel flow dialyzer
- 1948 Skeggs and Leonards. Counter current flows

Twin coil dialyzer, developed by Kolff (1955)



Prototype of the arterio-venous shunt developed by Quinton et al. in 1960



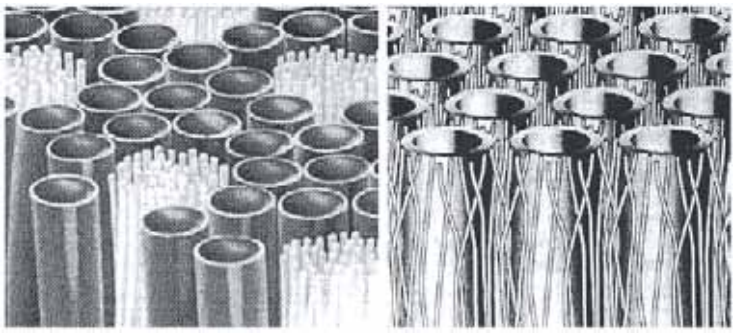
History of hemodialysis

- 1960 Kiil. Two layer cuprophan dialyser
- 1963 Acetate → Bicarbonate
- 1968 Stewart. Hollow fiber dialyzer
- 1970s: increasing efficiency, shortening time, biocompatability, minituarisation.
- 1971 Babb. High fluxes devises
- 1972 Synthetic membranes
- 1975 Schultheis. Volumetric control method of ultrafiltration flow
- 1980s Acitate toxicity

Modern hemodialyzers

- Permit complete manipulation of the dialysate composition, temperature, flows and pressures to improve problems of metabolic acidosis and electrolyte balance
- Most dialyzers today resemble ones that were 30 years ago but there are a number of changes…

Improvements of fiber bundle



Gastaldon. Special fiber cutting technology
Special fiber crossing
Dimensions of fibers

Improvements of housing

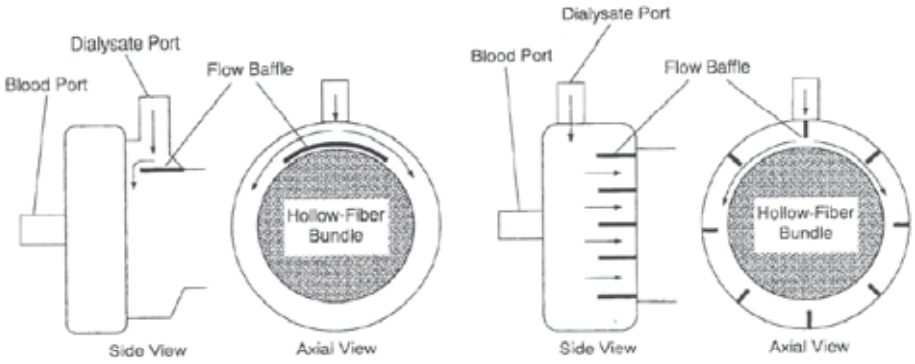
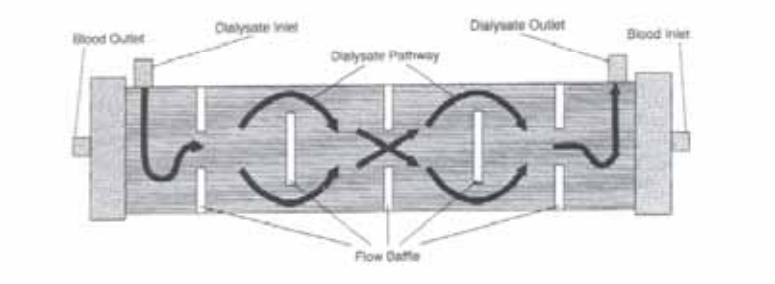
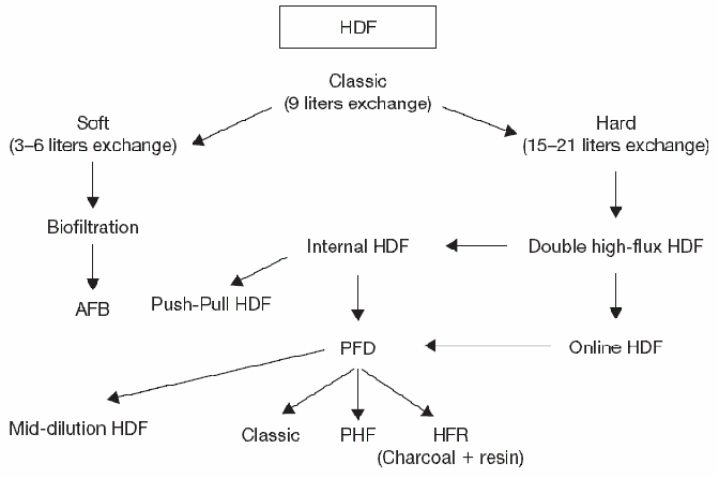


Fig. II-2: Flow baffles in a hemodialyzer: semi rounded flow baffle (left panel) and internally finned flow baffle (right panel), adapted from Poh et al. [133]



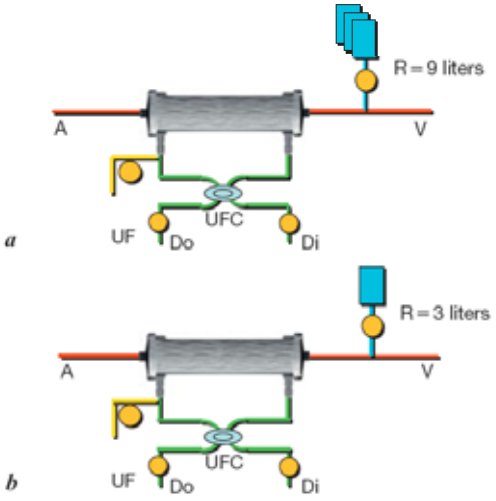
double segmental baffled module, adapted from Wang et al. [134]

Hemodiafiltration techniques

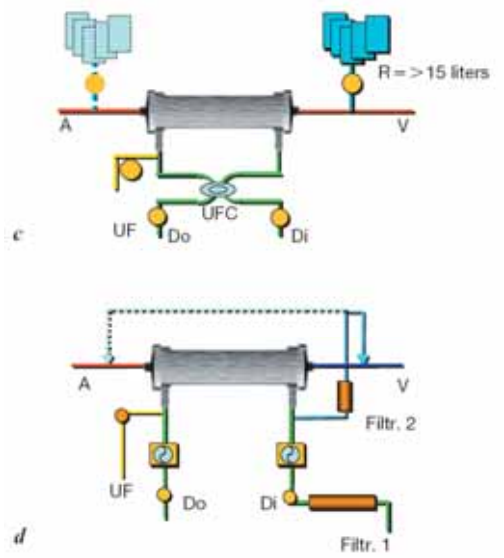


AFB = Acetate-free biofiltration; PFD = paired filtration dialysis PHF = paired HDF.

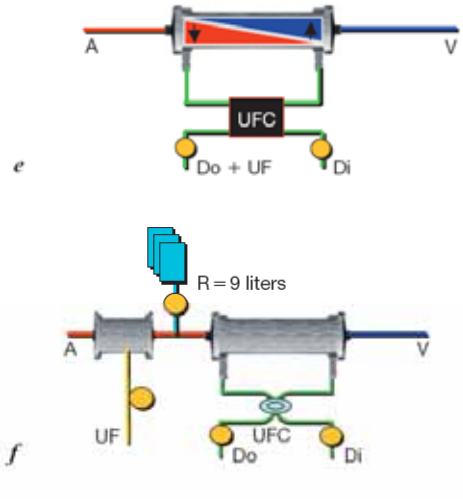
Classic HDF
and Soft HDF or biofoltration.



Hard(high-volume) HDF and Online HDF



Internal HDF(high-flux dialysis) and Paired fltration dialysis.



Mid-dilution and Push-pull HDF